

Shared mediated workspaces

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Abstract

Shared mediated spaces provide viable alternatives for meetings and interactions. The development of collaborative mediated workspaces and shared negotiation spaces will have a fundamental impact on all human practices. Previous design-led research, has identified spatial design concepts, such as mediated gaze, and spatial montage, which, if unaddressed, may be said to impose friction, and thus impact negatively on the experience of mediated presence. The current paper discusses a set of conceptual tools for presence design, in relation to a prototype that is currently being developed by an interdisciplinary academic work group: The Mediated Sketching Table. The prototype combines analogue and digital interaction tools and technologies including HTML5 and WebRTC. Here, we present our initial observations when using the prototype and discuss possible ways to overcome design friction in the prototype. We acknowledge that mediated presence cannot be ensured by design or technology alone. However, by monitoring various design features, presence designers can seek to reduce the friction that otherwise inhibits mediated presence, mutual trust, knowledge-sharing, and teamwork efficiency.

Keywords: presence design, spatial design, architecture, mediated gaze, spatial montage, shared mediated space, trust, knowledge-sharing, teamwork, design friction, ICT-mediated human activity, ethics, sketching, witnessed presence, mediated presence.

1. Introduction

Mediating Presence is a project within ICT Labs of the European Institute of Technology, carried out in 2012

as a collaborative effort by an interdisciplinary group of researchers. Our group seeks to combine a variety of analogue and digital tools to design a shared mediated workspace between three different locations. Our presence design research explores the combination of informal and formal collaboration that can be linked to the concepts of trust, witnessed presence, social connectedness, social affinity and serious games. We use workshops to combine theoretical reflection with rapid prototyping sessions in which we take the role as users. Our workshops usually attract an interdisciplinary group of 15 to 20 researchers.

Previous design-led research has shown that mediated spaces can provide sufficient audiovisual information about the remote space(s) and other person(s), allowing the subtleties of nonverbal communication to inform the interaction (e.g. IJsselsteijn 2004; IJsselsteijn & Riva 2003). In designing for presence, (certain) spatial features, such as the spatial extension of the remote space, have an effect on the user's experience of mediated interaction; and of witnessed presence (Nevejan 2007; Gullström 2010, 2011; Gill & Nevejan 2011). We hypothesize that certain spatial tools play an important role in the processes in which trust and consensus are established and therefore have a probable impact on knowledge-sharing also with an effect on teamwork and its ethical considerations.

IJsselstein (2004) identified four properties necessary for mediated presence to be established, namely (1) Attention, (2) The environment itself needs to have spatial extent and immersive qualities, (3) an ongoing construction of a sense of place has to be triggered, and (4) feedback from the remote environment should be swift, consistent and reliable in response to real time sensory motor probing. Our study is equally informed by research that has determined factors that may contribute to poorer synchronizing (Argyle & Cook 1976); and 'frictions' (Davenport & Prusak 1998) that inhibit

knowledge-sharing in human interaction and collaborative co-present contexts. These are, for example, mutual gaze and trust. In effect, to be able to achieve mutual gaze has been observed as a key element in establishing trust, also in mediated interaction (Heath & Luff 1992a, Heath et al 1995, Rocco 1998, Acker & Levitt 1987, Ishii & Kobayashi 1992, Ishii et al 1998, Fullwood 2006). As noted by Caroline Nevejan (2007) trust is a prerequisite to the individual experience of presence in mediated environments, contributing a ‘sense of being there’ or of ‘non-mediation’ (IJsselstein & Riva 2003; Lombard & Ditton 1997; Held & Durlach 1992).

Gullström (2010) illustrates several spatial design concepts (e.g. mediated gaze, spatial montage, shared mediated space), which, unaddressed, may be said to impose friction, and thus impact negatively on the experience of witnessed mediated presence (Nevejan 2007). Mediated presence cannot be ensured by design. However, by acknowledging that certain features are related to spatial design, a presence designer can monitor them and reduce the ‘design friction’ that otherwise may inhibit trust and knowledge-sharing.

In order to test whether these design considerations can improve user experience, mutual trust, and team efficiency we designed a “Mediated Sketching Table”. The prototype is a mediated space shared by three spatially separate parties. The three users can all see each other and have a shared work (sketching) area. Because of the three-way connection, the mediated sketching table provides a number of design challenges to overcome. In the design of the mediated sketching table we found it important to use relatively low-cost equipment and web-based commercial freeware, combined with innovative digital tools, such as provided through HTML5 and WebRTC.

The Mediated Sketching Table is different to, for example, the National TeleImmersion Initiative of Henry Fuchs (see <http://www.advanced.org/tele-immersion/History.html>), in that shared drawing and frontal representation are separated whilst situated in a spatially sound way. The Mediated Sketching table puts the focus on the shared activity leading to a shared space where people can augment drawings on paper, optimizing each other’s knowledge, while looking up and see the non-verbal response in the comfort of their own working environment. This approach easily accommodates inclusion of physical artifacts (e.g. a phone with a picture) in the shared space to emphasize something related to the shared activity.

Today, many people use ‘Skype’, ‘Google Hangout’ or other (freeware, web-based) collaboration tools, and

our interest is to combine their possibilities by using a variety of surfaces to facilitate interaction. The prototype allows us to explore the combination of vertical and horizontal surfaces that may be used in presence design in order to prepare for trust-building and other prerequisites for collaboration in mediated spaces. We are not satisfied with seeing our colleague in a small window on the small screen of the laptop. There is no space left for the documents we also try to collaborate on. Where shared documents should be placed and where we want to see each other are therefore two fundamental questions that still need answers. This is particularly interesting to us because our group focuses on the collaboration between three parties which makes the spatial problems even more complicated. Further, if in shared mediated spaces, one can add large projections of a remote interior, the environment behind your colleague becomes visually accessible: you become part of the other person’s work place, you can develop an informal affinity, and you can develop a social collaboration.

Placing objects on a shared work area, which triggers physical reactions in a remote location, contributes to mediated presence (e.g., Ishii 1992). Of particular interest to our research project, is the contribution from the TU Delft Interactive Intelligence Group on the concept of negotiation, negotiation processes and various supports for bidding, strategic management etc. Based on this, we identified a crucial moment in such negotiation processes, which we want to facilitate, and that centres on ‘placing your bid on the table’. This can be generalized to a variety of meeting situations where you want to share an item by placing it strategically on the table. It may be enough that the item is seen by the others, but sometimes this is not enough, it may require something more to have the desired impact and effect in the remote location.

2. Prototype design

Our work on the Mediated Sketching Table, aka ‘Shared Negotiation Surfaces’, started in February 2012 as we were planning our first workshop (Stockholm 14-16 March 2012). At the workshop, a first prototype was set up in the EIT Presence Lab at KTH. This enabled us to make joint drawings from two different locations, and to play board games together. At each location, the mediated workspace consisted of a horizontal shared drawing surface and a vertical audio- and video-channel for face-to-face interaction with the other participants. A similar interior layout was achieved at both locations. Cameras were placed at eye-level to enable mutual gaze, however clearly visible to the viewer. To allow for a richer



Figure 1.A) Schematic drawing of the set-up. The intended three-party design of the Mediated Sketching Table indicates the implications for future workplace design where colleagues in different locations wish to collaborate closely using a shared horizontal work surface. The prototype described in this paper was limited to mediated interaction between two locations.

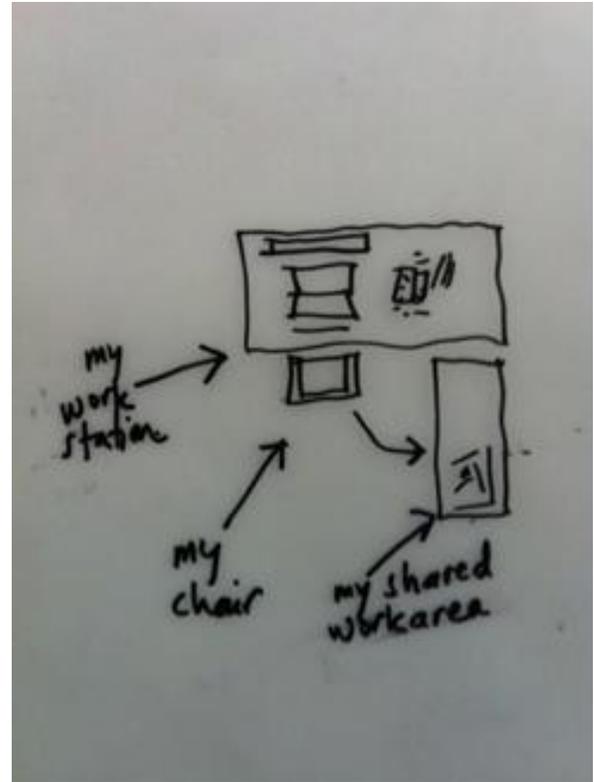


Figure 1.C) Top-down view of the workspace. Work station in front, shared work area and remote view to the side.



Figure 1.B) two-way implementation of the prototype seen at the KTH site.

interaction, each drawing space consists of a real drawing paper that is both filmed and projected. E.g., what is drawn locally is captured by an overhead camera and what others are drawing is simultaneously projected on the local drawing surface. It is assumed that drawing and sketching form part of team work. A film-clip from the prototyping in Stockholm can be seen here: <http://youtu.be/5A8NZBx6roA>, and here, as it was repeated at TU Delft two weeks later:

http://ii.tudelft.nl/event_photos/VIDEO0013.3gp



Figure 1.D) The interior prototype at KTH resembling an office workspace. From Delft, a sofa and a bookshelf can be seen in the background, behind Jesper to the left.

Our design was then elaborated in view of our second workshop (Delft, 17-20 June 2012). As seen in Figure 1, our sketches resulted in an interior layout, replicated at both locations.

The prototype initially consisted of various web based video systems, Skype, Apple FaceTime and Google Video Chat and Hangout for conveying the drawing and the communication data and to create a shared work surface, projected horizontally. This worked fine for conveying the initial feeling of presence, but the static user interfaces of these tools did not allow for any real experimentation, e.g. with overlaying video channels on top of each other or mixing windowed and full screen experiences. An alternative set-up was therefore also tested which deployed novel web technologies, such as HTML5 WebRTC for audio and video transfer. The aim is that the prototype can integrate various technologies on a horizontal surface, thus allowing users to choose between different interaction tools – freehand drawing using a conventional pen, web-based whiteboard software, WebRTC functionalities, placing augmented artefacts on the desktop – resulting in expected responses, reactions and dialogic interaction with a remote colleague.

HTML5 WebRTC is a loose term for the web technologies used for creating modern web applications and/or web sites. By basing the prototype on HTML5 technologies it allows for easier experimentation and very rapid prototyping using the JavaScript programming language for adding interactivity to the web applications. E.g. it is very easy, from a programming perspective to capture audio and video, display it on the computer screen and transform it using visual effects built in modern web browsers. Using WebRTC audio and video can be captured directly in a web browser without the need to install any additional software (i.e. so called plugins) which makes it very easy for new users to start using the shared workspace. For privacy reasons the users are asked each time the software requests access to local audio and video devices.

When audio and video has been captured is it sent over the Internet to the other participants in the shared workspace using a so called PeerConnection. Traditionally a web application that runs in the local web browser can only interact with other web servers, but in the case of real-time audio and video communication delay is very important and as part HTML5 this novel technology called PeerConnection allows for web applications to communicate directly with each other. The WebRTC framework supports negotiating and initializing this direct channel and the audio and video in shared workspace is sent directly over this channel to other participants.

As part of the shared workspace non audio and video data needs to be exchanged and this is handled using another web technology called WebSockets which allows

for bi-directional data exchange between a web browser and a web server. In the shared workspace a Node.JS server is used for message exchange. In the future the PeerConnection technology mentioned above will also include a data channel which will be used to replace the current WebSocket solution.

WebRTC and PeerConnection are very new technologies and at the time of writing (September 2012) they are still being developed and standardized. This means that WebRTC is currently not available in all web browsers but will be available in the near future. To date, Google Chrome, Mozilla Firefox and Opera have included WebRTC into their roadmaps. Microsoft has indicated that it will be available in Internet Explorer in the future while Apple has not indicated anything for Safari yet.

So far the prototype has gone through two iterations and from the perspective of technology the current direction is to extend the experiments with 1) so called tangible devices and augmented video to add more interactivity to the shared workspace and 2) adding computational photography to the face and upper body camera.

It aims towards the creation of a three-party workspace, where users are free to choose from a range of

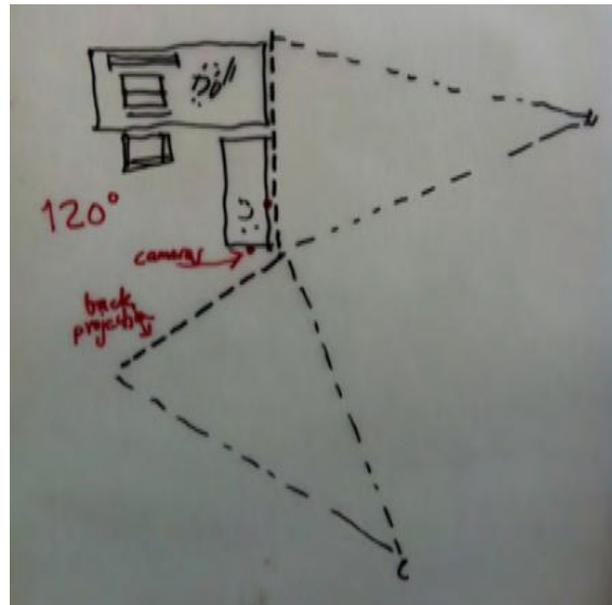


Figure 4. In this layout of a future workspace, you have your own computer screen in front of you, and to the side: a shared work area where three parties can collaborate. Using back projection (or large displays) your two colleagues will be placed at 120° angle in relation to you.

interaction tools on a horizontal shared work surface, whilst facing each others (120° angle) and with possibility to achieve eye contact.

3. Initial observations on user experience

We recently demonstrated the prototype at three events, namely at an ICT Labs workshop in Stockholm in March; a subsequent event in Delft in April, and later at the ICT labs workshop in Delft in June. While the first two demonstrations were local and established at two different parts of an interior space, the latter demonstration was set up between Stockholm and Delft.

The main purpose of the first two demonstrations was to reveal the added value of the shared working space on top of an ordinary life feed video connection. As such, we invited people to sit behind the prototype and play Tic Tac Toe on a piece of paper. One participant would draw the play field while the other player added either a cross or nul at a location in the playing field.

Our first observation was that most volunteers played this game naturally with hardly an instruction. Secondly, we also noticed that volunteers were suggesting to play all kinds of different games. One would propose a game and



Figure 5. At the first demonstration of the prototype in Stockholm it was clear that users appreciated the possibility to see both the hands, upper body as well as the interior background of the remote party.

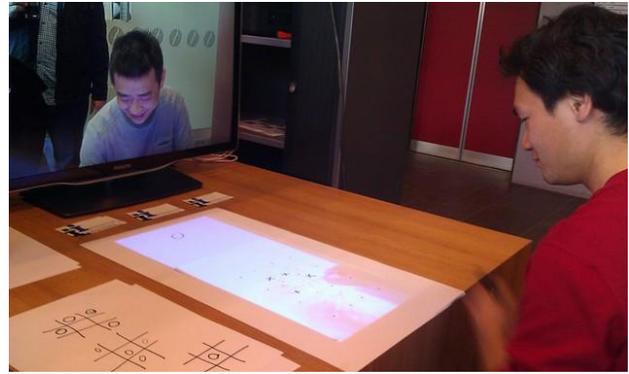


Figure 6. Two volunteers playing Tic Tac Toe at an event at Delft University of Technology Campus. The remote player (seen on the screen) drew the playing field and the player in the red shirt filled in crosses.

explain the rules using the shared working space and use the video feed to check whether thing got over 'ok'. This spontaneous play shows the intuitiveness of the prototype and the degrees of freedom.

It was also noted that when users were given the opportunity to elaborate on the game, they were happy to do so. In particular at the first demonstration in Stockholm, users took the liberty of drawing, writing and developing shared actions. The benefit of seeing the remote user's hand in action was quite clear. Continued discussions at this workshop helped us establish that drawing, scribbling and all kinds of (analogue) hands-on note-taking form an important part of current teamwork practices, in spite of the wide-spread use of web-based collaboration software. The group saw the potential for a shared mediated workspace that integrates analogue and digital interaction tools on various surfaces in the work environment.

At the ICT-labs workshop in Delft in June 2012, Robin Shaerverbeke, an architect and lecturer in drawing techniques at Sint Lucas School of Architecture, Ghent, was instructed to teach a student in Stockholm in real-time. He faced the student, seated by the Mediated Sketching Table which was now extended from Delft to Stockholm.

We found that the orientation from where people were facing each other was important. For learning to draw, Robin Shaerverbeke commented that the natural way to teach was to sit next to the student rather than facing the student. Further, he commented that the video connection showing the face of the student was less important than the shared workspace. The teacher's attention was mostly on the hands of the student and the drawing rather on the students' facial expressions.



Figure 7. Master student Jocke at KTH, in a remote teaching lesson with Robin, seated at his Mediated Sketching Table, at TU Delft.

Nevertheless, the users expressed a strong experience of connectedness and of working together.

We conclude that the prototype for the Mediated Sketching table already serves the following functions:

1. it has enabled (witnessed) mediated presence and thus illustrate the meaning of *shared mediated spaces* as an overarching concept in presence design;
2. it serve as an illustration of the above design concepts,
3. it is sufficiently integrated to a context of use and to an overall architectural design to be interpreted as a spatial extension or as part of a spatial interior/exterior, i.e. as an architectural element rather than as a technical device.

Based on the first positive (informal) observations, we have decided to implement the proposed workspace and spatial layout of the Mediated Sketching Table on a more permanent basis at the TU Delft experience Lab and the EIT Presence Lab at KTH from August onwards for extended experimentation on user experience.

While the evaluations were conducted using an architectural educational setting, the concepts of the mediated sketching table can easily be extended to other domains. The remote face-to-face communication can be extended by a shared workspace in any domain where actors collaborate on a shared activity while using a shared artifact. The shared workspace can be used not only for collaborative drawing, but also to discuss any shared physical artifact (e.g. a book, a phone, a picture). More concretely, two medical doctors can, while monitoring each other's non-verbal cues, negotiate the optimal treatment plan by looking at the plan and pointing

to elements of the plan. Alternatively, a number of naval military officers, while being in different ships, negotiate the optimal attack plan by pointing to the map to highlight potential threats or weaknesses of the plan. In addition, a navy officer X might put his phone on the shared space to reveal a picture to emphasize its claim.

4. Discussion

Teams that are separated by a spatial or temporal boundary experience complications in the development of effective interpersonal relations, experience more frequent communication mishaps, and have a lower awareness of team members' endeavours (Thompson & Coovert, 2006). Teamwork is affected negatively when a team of actors is distributed geographically or when actors are separated in time (Powell, Piccoli, & Ives, 2004).

In addition to a mutual understanding of the shared work, the common denominator in distributed settings is the failure to directly sense states of remote actors and observe actions or responses, which help to anticipate information needs and become aware of the weak spots in the team (de Greef, 2012). An actor, for example, observing the actions of its co-actor can not only anticipate the next step in their joint activity (Heath & Luff, 1992b) but also see whether the co-actor is coping adequately or requires assistance (backing-up behavior). Observing actions leads to anticipating the next step without requiring explicit calls to coordinate activities in order to optimize teamwork efficiency. Furthermore, the possibility to verify whether the co-actor copes and requires assistance leads to a team that is highly flexible in a variety of unexpected situations.

Observing actions can range from a quick observation of social contextual cues to monitoring performance. However, the actions, responses, and states of other team members are not directly observable when teams encounter a temporal or spatial boundary. This is the reason why applications like Skype are quite popular as it provides the remote actors a more rich image of the remote actor. However, these types of applications communicate only part of the important elements. To see what remote actors are doing, a mediated shared workspace is essential as it communicates more extensively what actors are doing and adds valuable information about the context in which work is achieved.

In the current version of the prototype, our focus has been on shared drawing and shared working surfaces. In the next iterations of the prototype we will address several of the spatial design concepts in Gullström's (2010) toolbox (e.g. *mediated gaze*, *spatial montage*, *shared*

mediated space), which, unaddressed, may be said to impose *friction*, and thus impact negatively on the experience of *witnessed mediated presence*. The strength of the current prototype lies in its capacity to integrate a range of different interaction tools which, arguably, benefit collaborative work by offering multiple choices to the user. While some of these have already been studied before (e.g. Microsoft research, Illumishare

<http://www.youtube.com/watch?v=ewmw8fUTa0Y&feature=youtu.be>), they have not been evaluated together. We plan to rigorously evaluate user experience with our prototype using standardized questionnaires on spatial and social presence in larger user groups. The broad spectrum of methodologies within our interdisciplinary research group will also allow us to evaluate other aspects that are for example related to design, ethics, and transmission efficiency.

Next, therefore, our plan is to add more interactivity by augmenting the video displayed on the shared drawing space. Several small (4x4 cm) tangible devices will be added to the workspace allowing the user to move them around. By interacting with them the user can bring digital elements onto the shared drawing surface. These can be pictures, drawings and movies as well as snapshots of the current drawing area. This could, of course, be done using a standard keyboard and mouse, but the idea is that tangible devices that can be moved loosely over the drawing surface, allow for more natural interaction and offers a wider range of interaction tools.

In future prototypes we will also expand on the video and audio streams that capture respectively the face / upper body, speech and spatial design. Images that come straight from a camera are strongly limited by the physical parameters of the cameras at both sides of the communication system. These limitations lead to important problems such as the Mona Lisa effect. That is, if the second party is not looking straight into the camera, for example because the camera is mounted above the screen, the observer of the camera's image will have the impression that the person does not make eye contact. In the next iterations of our prototypes we will thus explore the possibilities to include technologies from computational photography that allows creating virtual cameras (e.g., Yang & Zhang, 2004; Zhang et al, 2011). For example, using a camera in combination with an inexpensive depth ranger (e.g. a XBox Kinect) would allow us to compute the image that the camera would have seen if it were not located above or next to the screen but at the position on the screen where the eyes of the second person are. This computational approach would instantaneously resolve the "Mona Lisa" effect without

having to resort to using semi-transparent mirrors as is for example done in an autocue / teleprompter. We expect that the sense of social presence would increase substantially when more natural mutual gaze can be established using this technique.

When using virtual cameras we would also be able to render the image in such a way that the center of projection of the image on screen is yoked to the position of the observer. That is, if the observer moves, the perspective on screen moves as well. Yoking the image's center of projection to the position of the observer creates "motion parallax" in the display. That is, the speed at which objects in the picture plane move is dependent on the distance to the camera. It is well documented that motion parallax is a potent depth cue even when observer movements are small (e.g., McKee & Taylor, 2010; Neffs, 2011; Ono & Ujike, 2005; Ono & Wade, 2005; Rogers & Graham, 1979). More importantly, motion parallax creates stereopsis (the same qualitative depth experience that can also be obtained by showing disparate images to the two eyes, ie by stereovision or what is commonly referred to as "3D vision"). The user would have the impression of looking through a window into "the 3D room behind the TV" rather than at the 2D picture on the TV. Using motion parallax to create stereopsis is expected to increase not only spatial presence but also social presence. Other options using virtual cameras to improve the prototype would be to generate 3D stereo images, manipulate depth-of-field, and to combine different video streams for foreground and background.

From a user experience point of view we are also interested in which factors contribute to the impression that the displayed images form an virtual extension of the physical space instead of being a mere "pictorial space". We hypothesize that the prevailing light and audio conditions in both spaces should be brought into agreement.

Value Sensitive Design (VSD) (Friedman, 2004) is a design methodology centralizing around ethical values. The central focus of the VSD s research relates to eliciting values important to (in)direct stakeholders or actors to incorporate these early in the design process. The notion of VSD will become important while mediating presence facilitated by technology. A Google hangout session, for example, allows actors to *silently* take screenshots to capture a moment of significance (cf. moments to signify in the work of Nevejan, 2007). These pictures can be used and distributed easily using a number of tools (e.g. a post on facebook). In our meetings, this has happened a number of times without actors being aware of this. In a traditional meeting setting, taking such a picture would be

far more transparent as all those present at the meeting allowing those involved to object. This invasion of privacy will start to emerge even further when automatic recording and transcribing a meeting sessions becomes the norm. These are just some examples where privacy is affected and we will devote more attention to this and other values using the VSD methodology.

Today's Skype and video conferencing applications are used by millions of people, but do not provide the same experiences that real life interactions permit. Our future design and development concerns the combination of horizontal and vertical surfaces to create embedded virtual spaces that afford natural (verbal and nonverbal) interaction between users while safeguarding ethical values and normative rules. For these hybrid spaces to become resilient normative social environments, trust, truth, responsibility, accountability and non-verbal communication may be considered essential design components. In consideration of the above, the work presented is not conclusive, yet contributes to future workplace design, collaborative teamwork and management practices of our current network society.

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